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Title: Nuclear Weapon Materials Overview

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Nuclear Fundamentals Orientation Module 2

Nuclear Weapon Materials Overview

National Nuclear Security Administration
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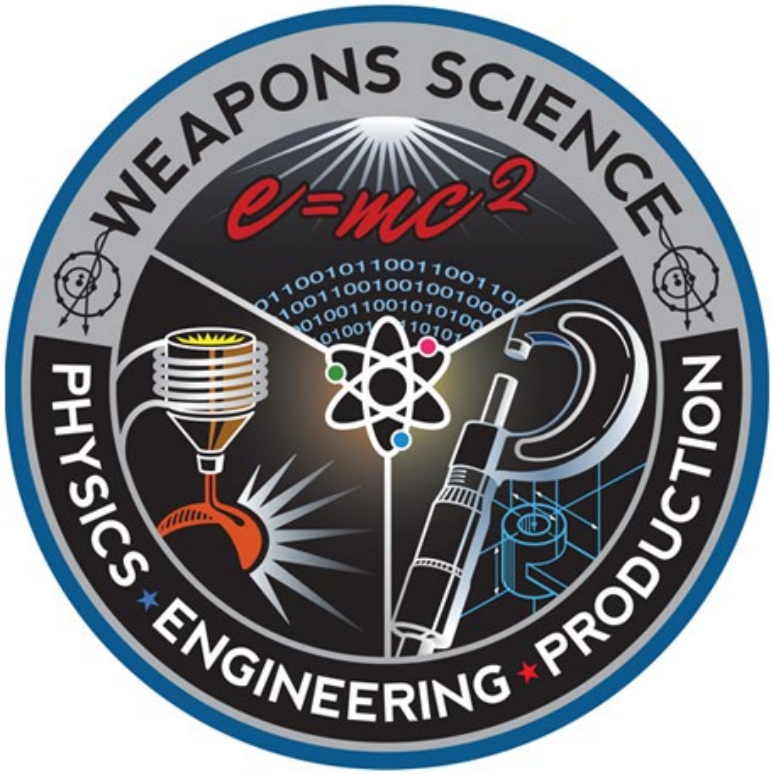
Nuclear Weapon Materials Overview



Presentation Overview:

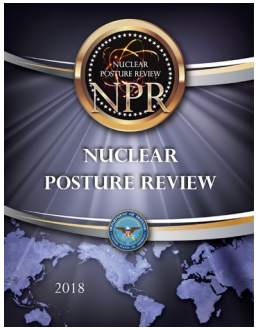
- Purpose
- Why Nuclear Materials are Important
- Background
- Material Science & Engineering Application
- Nuclear Weapon Materials
- References and Recommended Reading
- Questions

Purpose

- This presentation will familiarize you with the key materials used in nuclear weapons and why they are important to our nation
- It will discuss the *What, How and Why* of these materials to give you a better understanding of their function in our weapons
- Nuclear Weapon (NW) Materials consist of:
  - Metals (which include Special Nuclear Material (SNM))
  - Ceramics
  - Polymers
  - Composites (which include Energetics or explosives)

Why Nuclear Weapon Materials are Important!

Nuclear policy views by General Mark Milley, Chairman of Joint Chiefs of Staff, supports modernizing our weapons and facilities for maintaining our national security!



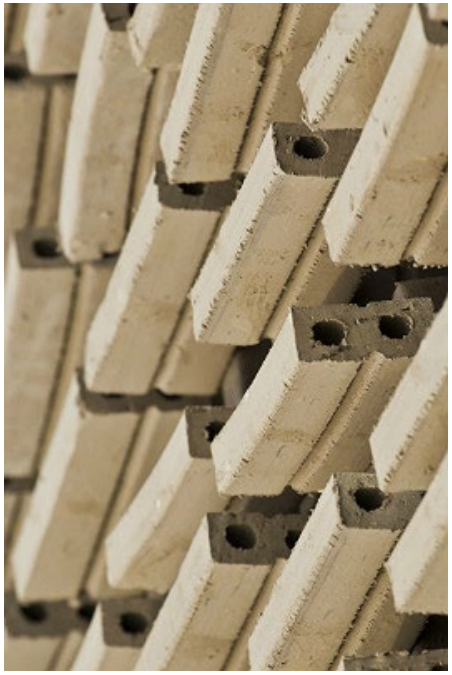
"I agree that nuclear modernization remains the number one modernization priority. I think accelerating modernization, where possible and fiscally responsible, should be a major component of this mitigation."

Advance Policy Questions 7/11/19 Confirmation Hearing

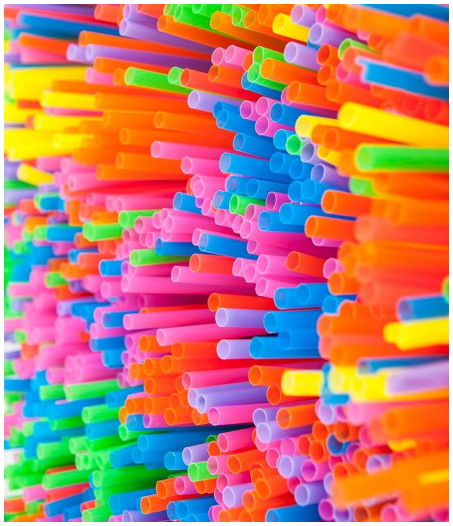
What do we mean when we say “Materials”?

Metals
- Aluminum
- Copper
- Steel (iron alloy)
- Nickel
- Titanium

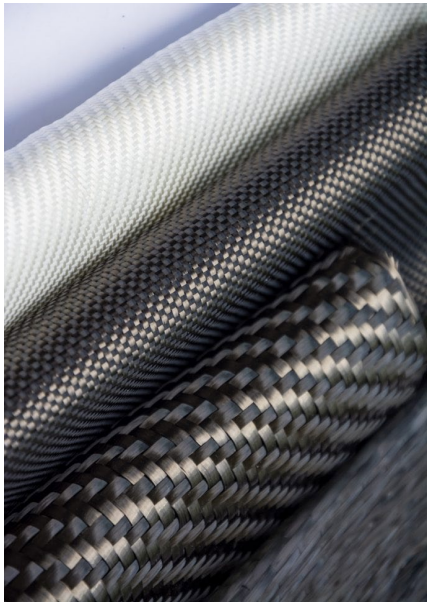
Ceramics
- Clay
- Silica glass
- Alumina
- Quartz



Polymers
- Polyvinyl chloride (PVC)
- Teflon
- Various plastics
- Glue (adhesives)
- Kevlar



Composites
- Wood
- Carbon fiber resins
- Concrete



Background - Metals

- Metals consist of alkaline, alkaline earth, metalloids and transition metals
- Metal alloys are mixtures of two or more metal and nonmetal elements (for example, aluminum and copper, Cu-Ni alloy, steel)
- Bonding: Metallic
  - No particular sharing or donating occurs. Electron cloud is formed (that is, free electrons)
  - Strong bonds with no hybridization or directionality
- Properties:
  - Electrically conductive (free electrons)
  - Thermally conductive
  - High strength – large capacity to carry load over x-section area (stress)
  - Ductile – endure large amounts of deformation before breaking.
  - Magnetic – ferromagnetism, paramagnetic
  - Medium melting point

Background - Ceramics

- Consist of metal and non metal elements
- Typically a mixture of elements in the form of a chemical compound, for example Al_2O_3 or glass
- Three types: composites, monolithic and amorphous ceramics
- Bonding covalent – ionic
  - Typically covalent. In some cases highly directional covalent bonding
  - Ionic in case of SiO_2 glasses and slags
- Properties:
  - Wear resistant (hard)
  - Chemical stability: corrosion resistant
  - High temperature strength: strength retention at very high temperatures
  - High melting points
  - Good insulators (dielectrics)
  - Adhesives
  - Good optical properties

Background - Polymers

- Polymers consist of various hydro-carbons (organic elements) with select additives to elucidate specific properties
- Polymers are typically disordered (amorphous) strands of hydrocarbon molecules, semi-crystalline or crystalline
- Bonding: Covalent-London Dispersion Forces
- Properties:
  - Ductile: can be stretched up to 1000% of original length
  - Lightweight: low densities
  - Medium strength: depending on additives
  - Chemical stability: inert to corrosive environments
  - Low melting point

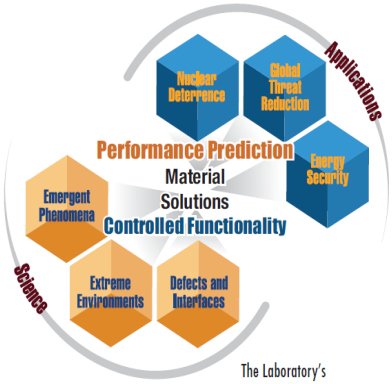
Background - Composites

- A mixture of two different materials to create a new material with combined properties
- Types of composites:
  - Particulate reinforced – discontinuous type with low aspect ratio
  - Whisker/rod reinforced - discontinuous type with high aspect ratio
  - Fiber reinforced - continuous type with high aspect ratio (naturally)
  - Laminated composites - layered structures (surf boards, skate boards)
- Bonding: depends on type of composite (strong-covalent, medium-solid solution, weak-tertiary phase layer)
- Properties: depends on composites
  - High melting points with improved high temperature strength: ceramic-ceramic
  - High strength and ductile with improved wear resistance: metal-ceramic
  - High strength and ductile: polymer-polymer

Materials Science & Engineering Application

What is materials science and engineering, and how is it applied here at Los Alamos?

- Materials Science and Engineering (MSE) combines engineering, physics and chemistry principles to solve real-world problems
- Everything is made of something - materials scientists and engineers investigate how materials perform and why they sometimes fail
- By understanding the structure of matter, from atomic-scale to millimeter-scale, we invent new ways to combine chemical elements into materials



The Laboratory's materials strategy diagram.

This approach helps NW designers choose what goes into a weapon

Nuclear Weapon Materials

- The four material types previously covered are all used in Los Alamos Weapons
- The three key NW materials we will discuss today are:
  - Composites – energetics/explosives
  - SNM metals
  - Polymers

How materials are evaluated generates the information needed to certify their use in weapons

Nuclear Weapon Materials - Composites

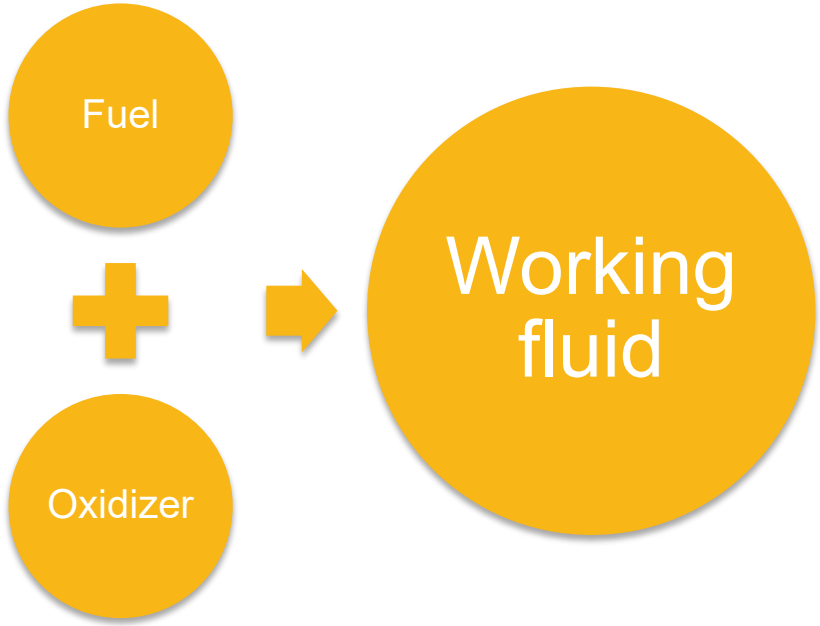
- Energetic Materials or High Explosives (HE) are the main composite used in NWs to initiate the nuclear detonation process
- There are multiple types of explosives used in various NWs in the stockpile
- LANL is advancing new HE candidates for the stockpile

Explosive testing at Los Alamos

Nuclear Weapon Materials - Composites

Useful explosive energy is based on three components

Chemical explosives are metastable chemicals or mixtures that store energy in chemical bonds. When these chemicals are excited enough to burn, they react very rapidly to form gases, and these product gases then expand to do work on their surroundings.

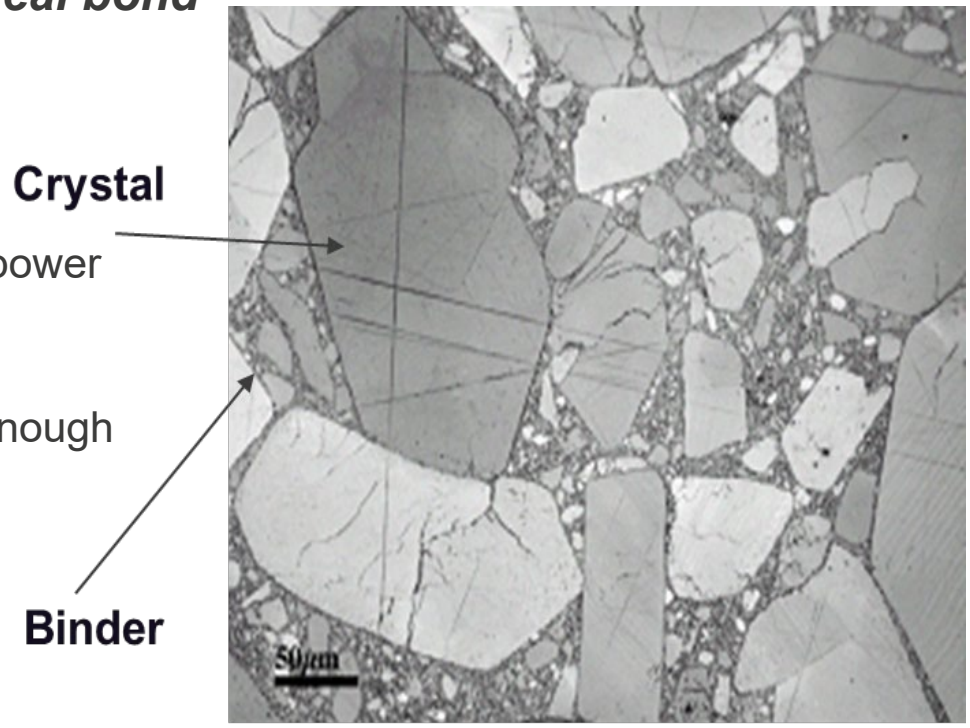


Nuclear Weapon Materials - Composites

What are Energetic Materials?

They are a composite compound or mixture that stores energy in a metastable chemical bond

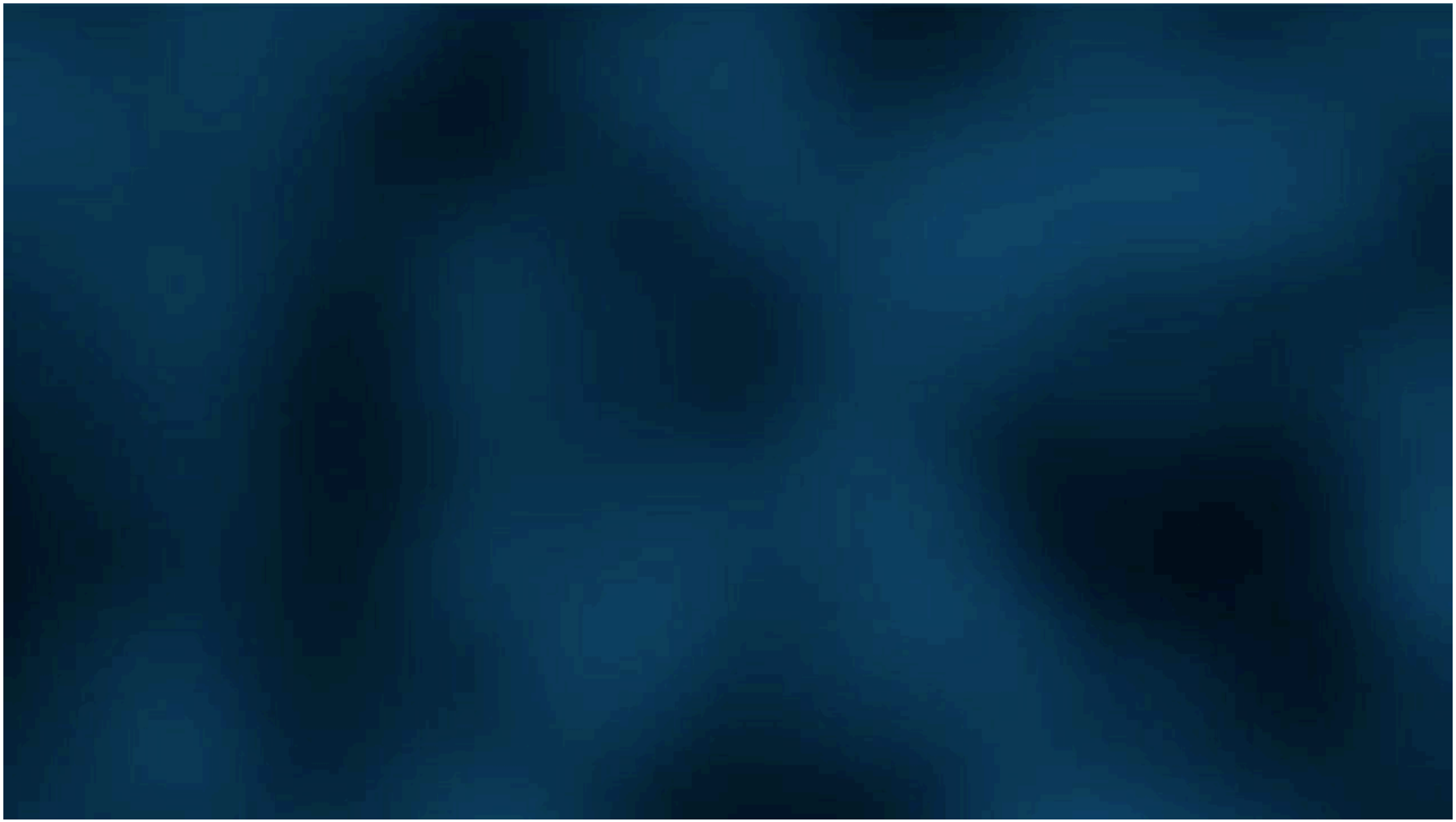
- Low Explosives deflagrate (burn)
  - Propellants
  - Useful for longer periods of sustained power delivery (~1,000,000 W/cc)
- High Explosives detonate (burn rapidly enough to drive a shock wave)
  - Explosives
  - Useful for short periods of immense power delivery (~ 10,000,000,000 W/cc)



Microstructure of PBX 9501

Nuclear Weapon Materials - Composites

Plate Impact Loading Testing Video

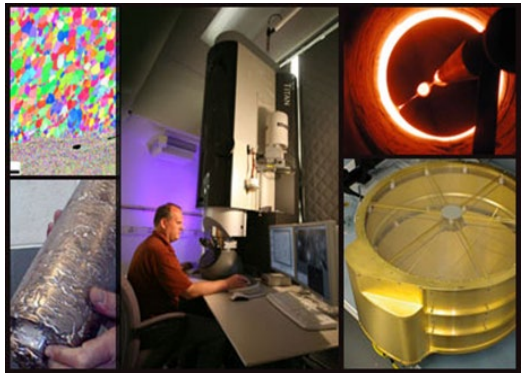


https://www.youtube.com/watch?v=uiSJOuRM_WE

Nuclear Weapon Materials - Metals

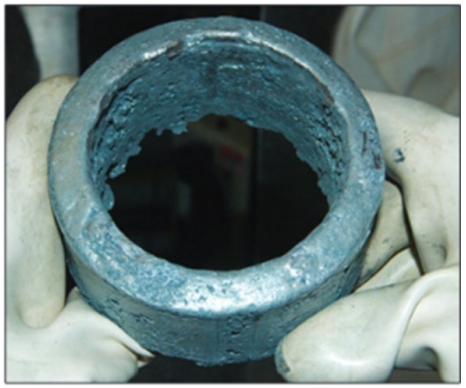
How are Metals used in NWs?

- Various metals are used in NWs
- They make up everything from equipment brackets and protective housings to the actual nuclear materials of the weapon
- Many are chosen for their strength, weight, and non-corrosive qualities
- The most critical of these metal applications are the SNM that were selected for their unique characteristics
- They generate the nuclear process (a large quantity of radioactive fission events) releasing huge amounts of energy in a very short time



Los Alamos shops excel in the capability to produce complex hardware and machining metals and alloys

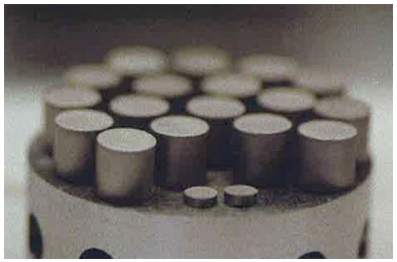
Ring of high-purity plutonium metal



Nuclear Weapon Materials - Metals

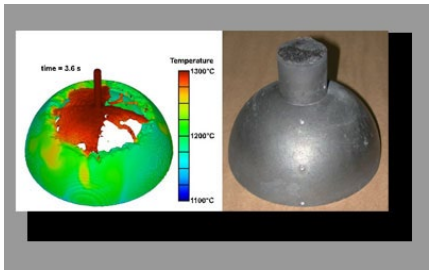
What are SNM metals?

- SNM is a refined form of two elements Uranium (U) and/or Plutonium (Pu); both are radioactive
- Uranium ore is found in nature and when processed can be refined (concentrated) into what is known as enriched uranium, a SNM
- Plutonium is generated by taking uranium and other materials and fabricating them into targets (long small-diameter fuel rods) that are made for use in a nuclear reactor
  - When fuel rods have been irradiated in a reactor for several days, Pu is generated
- Pu is then manufactured into what are known as NW Pits for use in a nuclear weapon
- Both Pu and enriched U are key radioactive materials used in NWs



Enriched UN/U3Si2 pellets

Comparison of the mold filling and solidification simulation to the final Uranium Basic-Hemi cast part



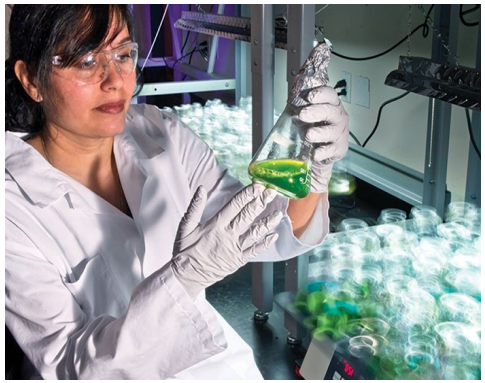
More information will be available if you will be working with these materials and you have acquired the appropriate security clearance

Nuclear Weapon Materials - Polymers

What are Polymers and how are they chosen for NW use?

- Polymers in NWs are not that much different from ones you see, or might come in contact with, in your everyday living
- Polymers, as mentioned before, consist of various hydro-carbons (organic elements) with select additives to provide specific properties
- Their use in NWs however, is tailored to what the specific weapon application may need to function properly; strength, elasticity, etc.
- They must have a life span equal to the weapon (~30 years or more) without degrading
- There is usually significant development involved to produce the product needed, if a commercial available polymer is not adequate
- Rigorous testing, in both custom or commercial chosen polymers, is used to prove the product will perform the desired function

Common use of polymer today is beverage container



Los Alamos scientists working to create plastics with bio-based manufacturing to be more environmentally compatible

Nuclear Weapon Materials - Polymers

Why do we use Polymers in NWs?

- Polymers have flexible characteristics that can absorb routine shocks and accidents or other events a weapon may be subjected to
- Most polymers are light weight, and thus offer a valuable asset to weapon designers
- They are usually reasonable to manufacture, can take on many unusual shapes/forms, and offer many options to the NW designer
  - Fill voids
  - Add a cushion effect to other components
  - As adhesives
  - Provide some other specific attribute for the weapon
- Polymers provide a modern alternative to some of the original materials used in older weapons that undergo refurbishment (Life Extensions or Alterations)

Polycarbonate is the strongest plastic that is 200 times stronger than glass

References and Recommended Reading

- Watch "Making Stuff," NOVA's 4-part series showcasing the materials that shaped history and those that may influence our future (https://www.pbs.org/wgbh/nova/series/making-stuff/)
- Materials Science and Engineering: An Introduction, Callister Jr., William D. & Rethwisch, David G.
- Materials: Engineering, Science, Processing and Design, Ashby, Michael F., Shercliff, Hugh, et al.
- Structure-Property Relationships under Extreme Dynamic Environments: Shock Recovery Experiments, Williams, Cyril L.
- Introduction to the Technology of Explosives, Cooper, Paul W. and Kurowski, Stanley R.
- Explosives Engineering, Cooper, Paul W.

- Get out and talk with people

Nuclear Weapon Materials Overview

SUMMARY:

- Purpose
- Why Nuclear Materials are Important
- Background
- Material Science & Engineering

Application

- Nuclear Weapon Materials
- References and Recommended Reading

Thank you!

Questions?

Email us: **NFO@lanl.gov**